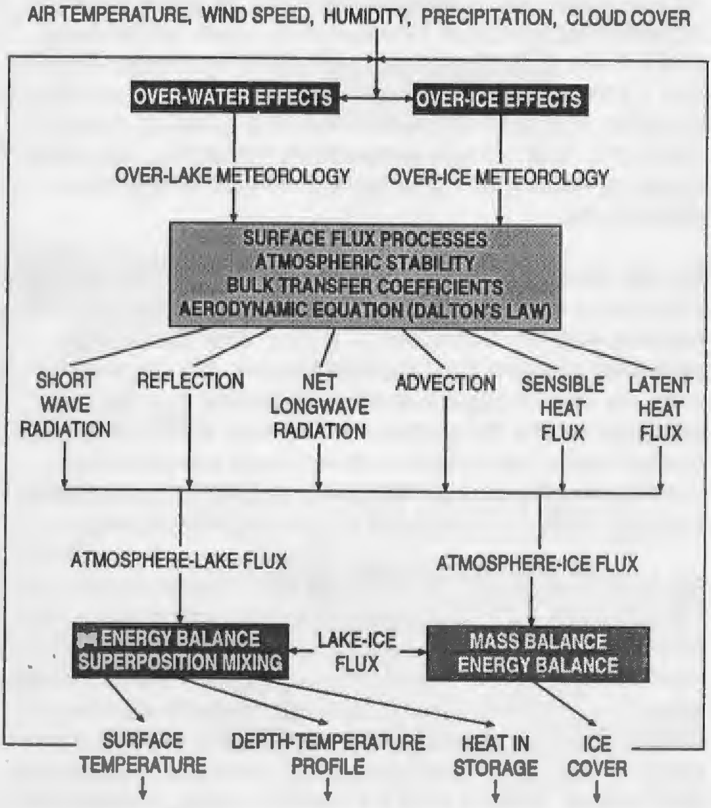
GLERL HYDROLOGICAL MODELING

PURPOSE. Great Lakes ***land surface modeling*** and ***thermodynamics modeling*** supports both GLERL's internal research efforts and external requests for estimates. GLERL's programs include its ***hydrological forecasting package*** and NOAA's nubile ***water resources forecasting system*** (WARFS). Also included is ***coupled hydrosphere-atmosphere research model*** (CHARM), ***climate change***, and ***climate transposition***. External requests include both ***US*** and ***Canadian governmental agencies*** and ***companies***, including the ***Environmental Protection Agency, US Army Corps of Engineers, National Weather Service, Climate Analysis Center, New York Power Authority, Canada Centre for Inland Waters, Canada's Atmospheric Environment Service, Canadian Climate Centre, Ontario Hydro***, and ***Hydro Quebec***.



LAKE THERMODYNAMICS MODEL. GLERL's lake thermodynamics modeling program emphasizes 3 aspects: ***temporal, vertical***, and ***spatial***. Regarding ***temporal***, GLERL ***continuously*** simulates surface fluxes over ***long*** time periods with their lumped-parameter ***lake thermodynamics model***. This allows exploration of long-term lake response to changes in driving parameters. Regarding ***vertical***, GLERL currently uses a ***superposition model*** of lake heat addition and storage to build temperature-depth profiles that reflect lake characteristics. This model will be augmented with further consideration of lake circulation and three-dimensional lake thermodynamics. At present, this model is a ***one-dimensional depth model***. Regarding ***spatial***, synoptic full-spatial consideration of lake evaporation and surface fluxes is now under development.

GLERL is processing satellite observations of lake surfaces and applying two-dimensional surface lake thermodynamic fluxes. Later considerations will look at wind fields, lake circulation, and dynamic atmospheric linkages in concert with dual mesoscale atmospheric-hydrologic model formulations.

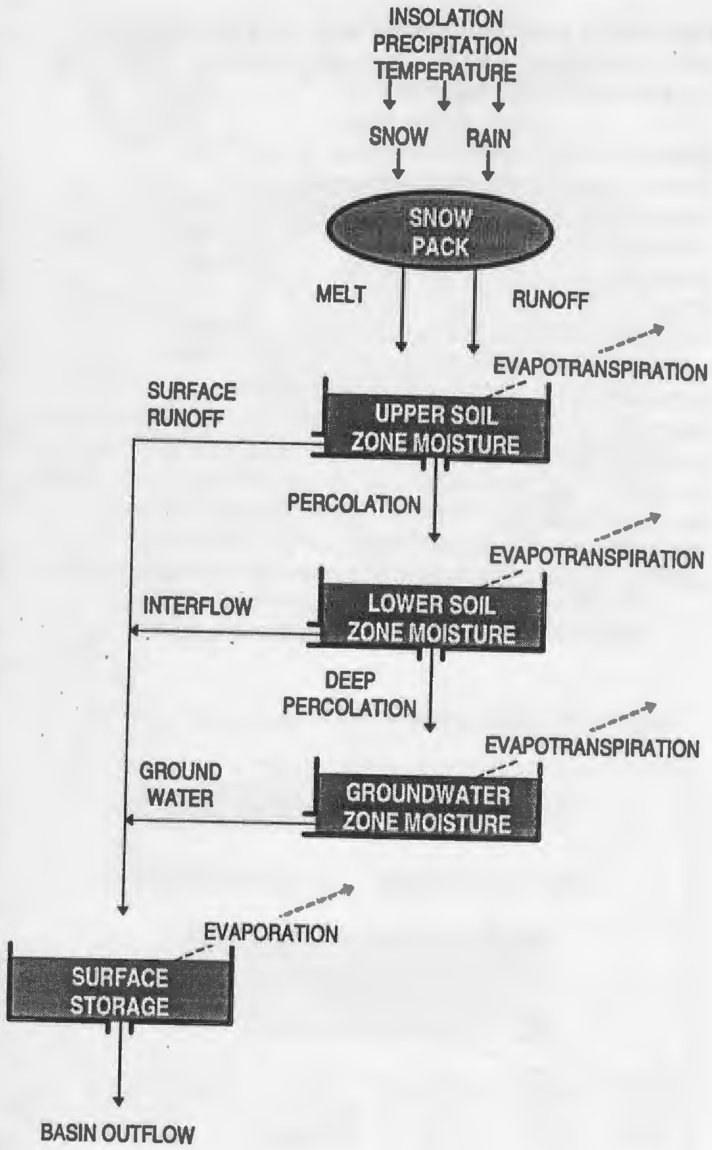
GLERL's Lake Thermodynamic Model ***empirically adjusts*** over-land data for over-water or over-ice conditions. ***Surface flux processes*** are represented for reflection and short-wave radiation, net long-wave radiation, and advection. ***Aerodynamic*** equation ***bulk transfer*** coefficients for sensible and latent heat are formulated with ***atmospheric stability*** effects. ***Energy conservation*** accounts for heat storage; ***superposition*** of heat additions or losses determines temperature-depth profiles. Each addition is ***parameterized by age*** and mixes throughout the volume. ***Mass and energy conservation*** account for ice formation and decay.

GLERL calibrated the model to observed water surface temperatures for each lake surface with daily historical meteorology of generally 1979-1990. They verified it with 23 years of water surface temperature, 38 years of water balance residuals, and 14 years of ice cover ***on all lakes***, and 8 years of depth-temperature profiles on Lake Superior and 1 year of independent surface flux estimates on Lakes Superior, Erie, and Ontario. The model correctly predicts turnovers, heat storage-temperature hysteresis, lake-wide seasonal heating and cooling, and vertical temperature distributions.

GLERL developed a ***2-d model*** from their ***1-d model*** which operates in either a ***simulation mode***, using average patterns with the 1-d model, or a ***near real-time mode***, extracting patterns from satellite images. For the near-term, we plan to publish an atlas of surface flux patterns, calculate energy flux patterns for 1991 to 1994, investigate diurnal surface temperature meteorology relationships, develop an empirical surface temperature ice cover model, and incorporate *CoastWatch* data and ***GOES*** images.

SURFACE RUNOFF MODEL. GLERL's Large Basin Runoff Model (LBRM) consists of moisture storages arranged as a serial and parallel ***cascade of "tanks"*** to coincide with the perceived basin storage structure. Water enters the snowpack, which supplies the basin surface (***degree-day snowmelt***). Infiltration is proportional to this supply and to saturation of the upper soil zone (***partial-area infiltration***). Excess supply is surface runoff. Flows from all tanks are proportional to their amounts (***linear-reservoir flows***). Evapotranspiration is proportional to available water and to sensible heat (***complementary concept***). ***Mass conservation*** applies for the snowpack and tanks; ***energy conservation*** applies to evapotranspiration. Complete analytical solutions exist.

The dynamic linkages (two-way dynamic feedback of heat, momentum, and moisture fluxes) between the atmosphere and the earth's surface are now recognized as essential in modeling atmospheric and hydrologic processes. We want to refine our models to include these linkages by using gridded land surface parameterizations at spatial scales of 1 to 30 km and temporal scales consistent with atmospheric models. Benefits of this research will be improved short-



term and seasonal forecasts and "nowcasts" of lake evaporation and temperature, runoff, and basin moisture conditions. Linking surface hydrology models with atmospheric models will result in more accurate estimates of regional and local impacts of climate change. Currently, we are evaluating state-of-the-art land surface parameterizations applied to the Great Lakes region, acquiring spatial land surface and meteorological data and incorporating advancements at finer resolutions, and refining and enhancing our gridded land surface parameterizations.

FUTURE DIRECTIONS. The land surface hydrology and lake thermodynamic research is being performed cooperatively with GLERL's "Coupled Hydrosphere Atmosphere Research Model (CHARM)" research. CHARM will use coupled models of the atmosphere, lake thermodynamics, and land surface hydrology to understand how the Great Lakes affect weather and climate, and vice versa.

This research will contribute to NOAA's Water Resources Forecasting System (WARFS), a joint program of the National Weather Service and GLERL. WARFS will capitalize on the NWS modernization of its meteorological forecasting and data collection services to provide better forecasts of stream flows and large lake water supplies, with extended lead times (up to six months). WARFS is NOAA's top priority initiative.

Although this research is focused on the Great Lakes Basin, results of the work will contribute to the Global Energy and Water Cycle Experiment's (GEWEX) Continental-scale International Project (GCIP), conducted under the auspices of the World Climate Research Programme. The objectives of GCIP are to determine the variability of the earth's hydrological cycle and energy exchange budget over a continental scale, to develop and validate techniques for coupling atmospheric and surface hydrological processes in climate models, and to provide a basis for translating the effects of future climate change to impacts on regional water resources. The focus of GCIP is the Mississippi River Basin. GLERL participates in the GCIP Hydrometeorology Subpanel and GCIP workshops, and has provided site proposals for the 1997 field studies.